OPTIMIZATION OF SURFACE TEXTURE IN MILLING USING RESPONSE SURFACE METHODOLOGY

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. This project has not been accepted for any degree and is not concurrently submitted for the award of other degree.

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ABSTRACT

This project deals with the effects of three parameters chosen on the surface texture of Aluminum 6061 by using milling. The main objectives of this project are to investigate the parameters for surface texture in milling, to obtain the optimum surface texture using Response Surface Methodology and to recommend the best machine parameter that contributes to the optimum surface roughness value. The study of this project covers on the limitation of cutting speed range (100 to 180 mm), feed range of 0.1 to 0.2 min.mm and depth of cut range 1 to 2 tooth.mm. The 15 experiments (1 experiment consist of 1 pass that 90mm in length) are done by using manual coding of CNC Milling Machine, Perthometer for surface roughness testing and Metallurgical Microscope for surface texture testing. The result and data taken from these procedures were analyzed by using Response Surface Methodology (RSM) of Minitab Software. The model is validates through a comparison of the experimental values with their predicted counterparts. From the results, it indicates that from the RSM method, the first order gives 73.14% accuracy and the second order gives 81.43% in accuracy. The proved technique gives opportunities for better approach that could be applied to the calibration of other empirical models of machining.

ABSTRAK

Projek ini berurusan dengan kesan-kesan oleh tiga parameter yang telah dipilih ke atas corak permukaan Aluminum 6061 menggunakan kaedah penggilingan. Objektif utama projek ini adalah untuk mengetahui parameter-parameter untuk corak permukaan menggunakan kaedah penggilingan, mendapatkan corak permukaan yang optimum menggunakan kaedah *Response Surface Methodology* dan mencadangkan parameter mesin yang terbaik yang menyumbang kepada kekasaran permukaan yang optimum. Projek ini merangkumi sekatan kepada skala kelajuan pemotongan (100 hingga 180 mm), jarak tujahan dari 0.1 hingga 0.2 min.mm dan kedalaman pemotongan berskala 1 hingga 2 tooth.mm. 15 eksperimen (1 eksperimen merangkumi 1 laluan berjarak 90 mm) dilakukan menggunakan kaedah pemasukan kod secara manual menggunakan *CNC Milling Machine, Perthometer* untuk ujian kekasaran permukaan dan *Metallurgical Microscope* untuk ujian corak permukaan. Keputusan dan data yang di ambil dari prosedur eksperimen ini di analisis menggunakan *Response Surface Methodology (RSM)* dari *Minitab Software.* Model ini disahkan melalui perbandingan nilai yang diperoleh daripada eksperimen dan juga dengan nilai ramalan. Daripada keputusan tersebut, ia menunjukkan dengan kaedah RSM, order pertama member ketepatan sebanyak 73.14% and order kedua ketepatan 81.43%. Teknik yang telah dibuktikan ini member peluang-peluang untuk pendekatan yang lebih baik yang boleh digunakan dalam kaliberasi model-model mesin empirical yang lain.

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μin	microinch
μm	micrometer
V	cutting speed
D	diameter of the cutter
N	revolution per minute
η	curvature
k	number of variables
x_1	cutting speed
x_2	feed
x_3	depth of cut

LIST OF ABBREVIATIONS

RSM	Response Surface Methodology
ASA	American Standards Association
BS	British Standards
NC	Numerical Controlled
CNC	Computer Numerically Controlled
FMS	Flexible Machining System
CAD	Computer Aided Design
DoE	Design of Experiment

CHAPTER 1

INTRODUCTION

1.1 IMPORTANCE OF STUDY IN SURFACE TEXTURE

Different parts need different finishes for different reasons. Optimization of surface texture is important because it will affect the overall production of parts either in direct or indirect ways. Some criteria that are affected by the surface texture are:

1.1.1 The cost impact

When part performance problems arise, it leaves no alternative other than simply tightening Ra tolerance. This usually results in a change to a different finishing process and additional manufacturing cost to correct a problem that may not have been related to average roughness at all. In fact, there is little correlation between average roughness and function.

1.1.2 Relating profile to function

The surface of an object is the boundary that separates it from another object, substance, or space. Surface texture is the deviation of the actual surface profile from the nominal surface, including roughness and waviness. This deviation (mean and maximum peak height, peak distribution, waviness) is what determines the functional characteristics of a surface.

The challenge is to understand the relationship between the texture of an engineered surface and its intended or desired function. This requires the use of analytical surface-texture measuring instruments to define, specify, and control critical surfaces.

1.1.3 A new competitive environment

Manufacturers are being asked to respond to the increasing demand for a better quality and higher performance. Improved methods of surface-texture analysis, specification, and control are critical to that response, yet they are often overlooked. European manufacturers, largely in response to higher energy costs and the need for high-efficiency engines recognized the limitation of Ra some time ago. So, they developed new parameters to evaluate surfaces with the same average roughness, but different performance characteristics.

Multiple parameter evaluation using these parameters in meaningful combinations based on functional application requirements provides a number of significant benefits. First is the ability to develop a more definitive specification that, if met, assures that the surface will perform as intended. Secondarily, multi parameter surface texture measuring instruments provide manufacturing engineers with the ability to analyze and optimize the process, and thereby reduce manufacturing cost.

The challenge is to make the investment in analytical surface-texture measuring equipment, do the empirical testing necessary to understand the relationship between surface texture and function, develop more meaningful specifications by involving the design engineers in the process, and use this new knowledge and equipment to improve performance and reduce costs.

Optimization is an alternative to get the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. In comparison, maximization means trying to attain the highest or maximum result or outcome without regard to cost or expense. Practice of optimization is restricted by the lack of full information, and the lack of time to evaluate what information is available. As in milling, optimization of surface texture is one of the methods to minimize the operations hours and reduce the cost of production without ignoring other side effects.

1.2 PROBLEM STATEMENT

From the previous study in milling, mathematical models were developed for the determination of cutting forces, torque and specific cutting energy for both sharp and worn milling cutters. Extensions of the models were performed for the prediction of cutting forces in the contouring operations and in the presence of tool-run out offset. The model was also applied for the determination of cutter immersions from the measured cutting force data.

This study focused more on surface texture and it optimization in order to get the optimum surface texture. Parameters used in surface texture were cutting speed, feed and depth of cut. The Response Surface Methodology guided through the process of fitting the predicted and experimental data, the pattern recognition and also clustering.

1.3 OBJECTIVES

The objectives of this project are:

i. To investigate the parameters for surface texture used in Milling.
ii. To obtain the optimum surface texture in milling using Response Surface Methodology.
iii. To recommend the best machine parameter that contributes to the optimum surface roughness value.

1.4 SCOPES

The study of this project covered on:

i. The limitation of cutting speed range (high, medium and low) range 100-180 mm.min
ii. The feed range 0.1-0.2 mm
iii. The depth of cut range 1-2 tooth.mm

CHAPTER 2

LITERATURE REVIEW

2.1 SURFACE TEXTURE

Scott and Qi (2001) stated that surface texture is defined as a degree of finish conveyed to the machinist by a system of symbols devised by a Standard Association, example American Standards Association (ASA) and British Standards (BS). Modern technology has demanded improved surface finishes ensuring proper functioning and long life of machine parts. Pistons, bearings, and gears depend to a great extent on a good surface finish for proper functioning and therefore, require little or no break-in period. Finer finishes often require additional operation, such as lapping or honing. The higher finishes are not always required on parts and only result in higher production costs. To prevent over finishing a part, the desired finish is indicated on the shop drawing. Information specifying the degree of finish is conveyed to the machinist by a system of symbols devised by Standard Association. These symbols provide a standard system of determining and indicating surface finish. The inch unit for surface finish measurement is *microinch (µin),* while the metric unit is *micrometer (µm).*

Regardless to the method of production, all surfaces have their own characteristics, which are collectively referred to as surface texture (Figure 2.1).

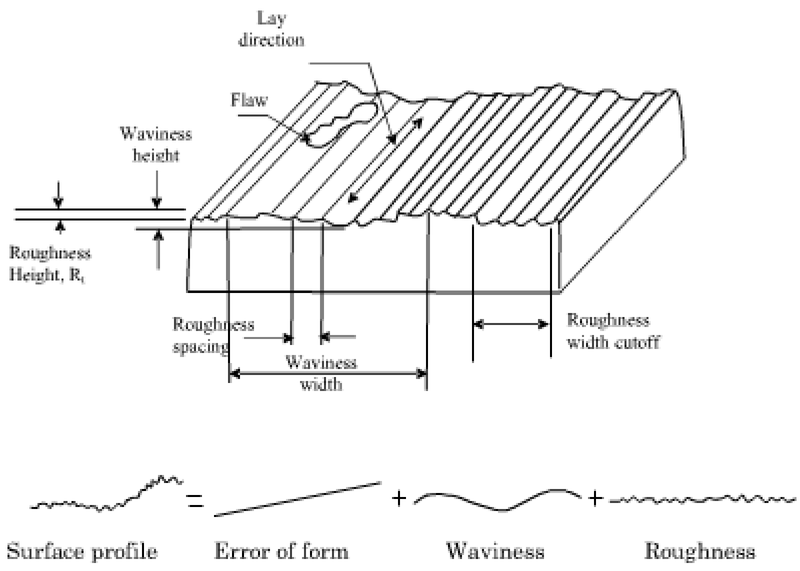

Figure 2.1: Standard terminology and symbols to describe surface finish

Source: http://www.engineersedge.com/surface_finish.htm

2.1.1 Flaws

Flaws or defects are random irregularities, such as scratches, cracks, holes, depression, seams, tears or inclusions. These defects can be caused during the machining or production process such as molding, drawing, forging, machining, holes caused by air bubbles during casting, crack and tears by forging and drawing process.

2.1.2 Lay

Lay or directionality, is the direction of the predominant surface pattern caused by the machining process and it is usually visible to the naked eye.

2.1.3 Roughness

Roughness is defined as closely spaced, irregular deviation on a scale smaller than that waviness. It is caused by the cutting tool or the abrasive grain action and the machine feed. Roughness may be superimposed by waviness.

i. **Roughness height, Ra**

Roughness height is the deviation to the centre line in micro inches or micrometers.

ii. **Roughness width**

Roughness width is the distance between successive roughness peaks parallel to the nominal surface in inches or millimeters.

2.1.4 Waviness

Waviness is a recurrent deviation from a flat surface, much like waves on the surface of water. It is measured and described in terms of the surface between adjacent crests of the waves (waviness width) and height between the crests and valleys of the waves (waviness height). Waviness can be caused by:

i. Deflection of tools, dies or work piece.
ii. Force or temperature sufficient to cause warping.
iii. Uneven lubrication.
iv. Vibration.
v. Any periodic mechanical or thermal variations on the system during manufacturing operations.

2.1.5 Profile

Profile is the contour of a specified section through a surface.

2.1.6 Microinch and micrometer

The unit of measurement used to measure surface finish. The microinch is equal to 0.000 001 inch and the micrometer equals to 0.000 001 meter.

They also developed expression of surface texture; more than 100 profile parameters and 40 areal parameters have been defined. The specification of surface texture is getting more and more complicated as shown in Figure 2.2. There is a large amount of surface texture specification and verification data with associated information regarding function requirements, manufacturing process and measurement that needs to be expressed, transferred, stored or analyzed. As more data is being collected, there is a need for sharing data and associated information effectively, to eliminate redundancy in data collection and analysis. However, formats currently being used do not convey all the required information of the component. In 2001, Bui of NIST applied Java and internet technology to develop an internet based surface texture analysis and information system. Muralikrishnan proposed the specification of a common XML language for expressing surface texture metrology data with related process and functional data in 2002. Other national measurement institutes have also attempted to establish reference software for profile surface texture analysis. Unfortunately, none of these achieved a complete and unambiguous expression of the surface texture for a connection between design, manufacture and measurement.

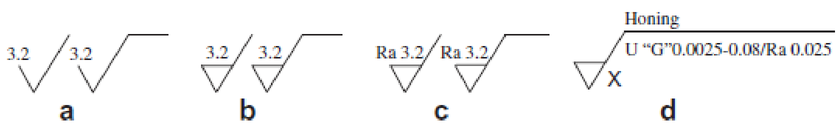

Figure 2.2: Different versions of the surface texture symbol used in the drawing. (a) The 1955 version, high specification uncertainty. (b) The 1965 version, up to 300% specification uncertainty. (c) The 1991 version, up to 30% uncertainty. (d) The ISP 1302:2002 version, low specification uncertainty.

2.2 MILLING MACHINE

The ability of a manufacturing operation to produce a specific surface roughness depends on many factors. For example, in end mill cutting, the final surface depends on the rotational speed of the end mill cutter, the velocity of the transverse, the rate of feed, the amount and type of lubrication at the point of cutting, and the mechanical properties of the piece being machined. A small change in any of the factors can have a significant effect on the surface produced. Table 2.1 shows the roughness height rating of some types of machining.

Table 2.1: Surface Roughness Average Obtainable by Common Production Methods

PROCESS	ROUGHNESS HEIGHT RATING MICROINCHES 2000 1000 500 250 125 63 32 16 8 4 2 1 0.5
Flame Cutting	---------XXXX----------
Sawing	------------XXXXXXXXXX---------
Drilling	---------XXXXXXXXXXXXXX------------
EDM	----------XXXXXXX--------
Milling	-----------------XXXXXXXXXXXXX-----------
Broaching	-------XXXXXXXX--------
Reaming	-------XXXXXXXX--------
Laser	XXXXXXXXXXXXXX----------
Burnishing	---------XXXXXXX-------
Grinding	--------------XXXXXXXXXXXXXXXXX--------
Honing	-------XXXXXXXXXXXXX--------
Polishing	-------XXXXXXXX------------------
Extruding	-------------XXXXXXX------
Investment Casting	------XXXX------------------
Perm Mold Cast	------XXXX------------------
Die Casting	------XXXXXX------

Yucesan and Guven (1992) stated that the milling process is one of the most important material removal processes suitable for a broad range of applications. Milling is a versatile material removal process. Complicated shapes, with close tolerances, can be machined using milling operations. Milling machines can have multiple axis for machining complicated surfaces. Compared to the nontraditional machining processes, a milling process can have a very high material removal rates making it one of the most economical process for material removal.

The milling process requires a milling machine, workpiece, fixture, and cutter. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the milling machine. It can move in three perpendicular directions. It may be flat, angular, or curved. The cutter is a cutting tool with many sharp teeth that is also secured in the milling machine and rotates at high